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ABSTRACT

Two experiments explored whether the facilitatory effect of context on lexical decisions is limited to words subjects generated when given the context as a prompt in a production task, or if the effect is wider in scope. The first experiment provided evidence of a wide scope of facilitation from single word contexts. In the second experiment, the contexts consisted of sentences with the final word deleted. Norms were collected to determine the most common completion for each sentence frame. The experiment yielded three main findings: (1) lexical decisions were fastest for words that were the most common completions; (2) among words not given as completions in the norming procedure, decisions were faster for words related to the most common completions than for words unrelated to the most common completions; (3) among words that were not produced as completions, decisions were faster for words that formed acceptable completions than for words that did not. These "relatedness" and "sentence acceptability" effects were independent, so that the relatedness effect held even when the target words formed anomalous sentence completions. To account for these results, a model combining two types of processes is required. In one such model, schematic knowledge operates upon a semantic network to activate particular nodes, and this activation spreads to related concepts. (Author)

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Technical Report No. 133

THE SCOPE OF FACILITATION OF WORD RECOGNITION FROM SINGLE WORD AND SENTENCE FRAME CONTEXTS

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Abstract

Two experiments explored whether the facilitatory effect of context on lexical decisions is limited to words subjects generated when given the context as a prompt in a production task, or if the effect is wider in scope. Experiment 1 provided evidence of a wide scope of facilitation from single word contexts. In Experiment 2 the contexts consisted of sentences with the final word deleted. Norms were collected to determine the most common completion for each sentence frame. The experiment yielded three main findings: (1) lexical decisions were fastest for words that were the most common completions; (2) among words not given as completions in the norming procedure, decisions were faster for words related to the most common completions than for words unrelated to the most common completions; (3) also among words that were not produced as completions, decisions were faster for words that formed acceptable completions than for words which did not. These relatedness and sentence acceptability effects were independent, so that the relatedness effect held even when the target words formed anomalous sentence completions. In order to account for these results, a model combining two types of processes is required. In the example combination model described, schematic knowledge (Rumelhart & Ortony, 1977) operates upon a semantic network to activate particular nodes, and this activation spreads to related concepts as in the Collins and Loftus (1975) model.

The Scope of Facilitation of Word Recognition From Single Word and Sentence Frame Contexts

It is well established that a linguistic context can facilitate the recognition of written words. This was first shown in studies in which brief tachistoscopic exposures of words were presented and recognition duration thresholds were measured (Pillsbury, 1897; Tulving & Gold, 1963; Morton, 1964). More recently, the lexical decision task has been used to study many aspects of context facilitation. In this task, subjects decide whether or not strings of letters form words, and reaction times and error rates are measured. In lexical decision studies, the context has generally consisted of an individual word presented either simultaneously with, or just prior to, the target word. In the prototype experiment (Meyer & Schvaneveldt, 1971), subjects saw two simultaneously presented strings of letters (e.g., bread butter, wine plame, nart thief) and decided whether or not both strings formed words. The pairs in which both strings formed words were of two types: those in which the words were associated (e.g., bread butter, nurse doctor) and those in which the words were unassociated (e.g., bread doctor, nurse butter). The result of interest is that reaction time to decide that both letter strings are words is less for the associated pairs than for the unassociated pairs. The same finding holds when the two letter strings are presented sequentially and only the reaction time to the second string is considered (Meyer, Schvaneveldt, & Ruddy, 1974). That is, an associated word context facilitates the lexical decision.

This paper is concerned with the scope or limits of context facilitation. More specifically, the question addressed is: What determines the set of words for which recognition will be facilitated by a given context? First single word contexts and then sentence frame contexts will be considered.

Three models found in the current literature offer accounts of facilitation from single word contexts. They are the spreading activation model (Collins & Loftus, 1975; Meyer, Schvaneveldt, & Ruddy, Note 1), the logogen model (Morton, 1969), and the verification model (Becker, 1976; Becker & Killion, 1977). In the spreading activation model (as described by Collins & Loftus, 1975), each concept in memory is represented by a concept node. From each concept node, there are links to other nodes which designate the properties of the concept. These properties are themselves concepts. For example, the node representing the concept apple is linked to nodes representing the concepts fruit, food, round, red, etc. The links have labels designating the types of relationships between concepts. The label on a link can itself be a concept, so any relationship can be represented. Each link has an associated strength or accessibility, designating how easily activation can traverse it.

According to this model, when context primes or activates a concept, activation spreads from that concept node along the links of the network, activating each node it reaches. The activation of a node by context makes that node easier to access, so less sensory information will be needed to access it. Activation is like a signal from a source that is attenuated as

it travels outward. The amount of activation dissipated as it traverses a given link is proportional to the accessibility or strength of that link. The total amount of activation that spreads from one concept to another is also affected by the number of intermediate paths connecting the two nodes. For example, if the node for vehicle is activated, activation will spread directly to the nodes for car, truck, bus, ambulance, etc. Some activation will then spread from each of these exemplars of vehicles to the others so, for example, the total amount of activation reaching truck will be somewhat greater than the amount that traversed the direct link from vehicle to truck. Therefore, the amount of activation that spreads from one node to another is a function of the number of paths between the nodes and the accessibility of the links in the paths. The value of this function reflects the relatedness of the two concepts. Context facilitation is predicted to occur whenever the concept named by the target word is related to the concept named by the context word.

In the logogen model, the basic structural entities are logogens, of which, it is postulated, there is one for each word in a person's lexicon. A logogen is a device that accepts both sensory and contextual information relevant to the word it represents. In reading, sensory information is in the form of visual attributes, contextual information is in the form of semantic attributes. The logogen registers the number of relevant attributes, regardless of their source, on an internal counter. When the counter passes a threshold value, the word represented by the logogen becomes "available," i.e., it is recognized. Context facilitation occurs

for a given word when the context provides some relevant semantic attributes, since these would increment the counter, thereby enabling the word to be accessed with fewer sensory attributes. Therefore, facilitation is predicted whenever the target shares a sufficient number of semantic attributes with the context.

The operations posited by the verification model are quite different. In this model, a word is recognized by means of a verification process which involves both selection and comparison. A word is selected from a verification set, and a prototype of this word is compared to the stimulus word. If a match is found, the word is recognized. If a match is not found, the next word in the verification set is selected and the comparison process repeats. Within this model, context affects the establishment of the verification set. When there is no context, this set is established according to an initial analysis of the visual features of the stimulus string. When there is a context, words semantically related to it comprise the verification set. Becker's only description of how this occurs is that it is similar to the activation of word detectors in the logogen model. If the presented word is in the context-induced verification set, the initial feature analysis process will be bypassed, thereby speeding recognition.

Many recent studies have used the lexical decision task to test specific aspects of these models and to explore further the associated context effect. Schvaneveldt and Meyer (1974) found that the facilitation effect occurs even when an unassociated word is introduced between the two associates (e.g., bread star butter). Meyer et al. (Note 1), Neely (1977),

Fischler and Goodman (1978), and Antos (in press) have used the sequential presentation procedure to study the effects of varying the delay between context and target words. Neely (1977) and Antos (in press) have explored whether the effect is due to conscious or automatic processes, as described by Posner and Snyder (1975a, 1975b). Shulman and Davison (1977) and James (1975) have examined changes in context facilitation of lexical decisions as a result of using different types of nonwords. Other studies (Meyer et al., 1974; Becker & Killion, 1977) have found that the magnitude of the context facilitation effect increases when the target words are visually degraded.

Although context facilitation has been the focus of much research, one issue that has not received sufficient consideration is that of the scope or limits of context facilitation. In most previous work, context facilitation has been demonstrated only for target words that subjects generate when given the context as a prompt in a production task. For example, in most studies which used single word contexts, the word pairs were derived from word association norms or from category exemplar production norms. With one exception (Fischler, 1977), no effort has been directed towards determining whether context facilitation is limited to these words, or whether it also occurs for words which subjects would not produce when given the context, but which are in some way related to it.[1]

This issue of the scope of context facilitation has been neglected in the theoretical work as well as the empirical work. In the available descriptions of the spreading activation, logogen, and verification models, the scope of context facilitation is never explicitly considered. However,

all three models predict that facilitation will be very general, not limited to those words subjects generate when given the context. According to the spreading activation model, facilitation will occur whenever the context and target are closely related. According to the logogen model, facilitation will occur whenever the context and target have a sufficient number of semantic features in common. Neither the structure of the network of nodes that determines relatedness nor the nature of the semantic attributes has been specified in any detail. However, it seems reasonable to assume that the degree of relatedness between pairs of concepts in Collins and Loftus' representation would be highly correlated with the number of shared features in Morton's representation. Therefore, these two models make similar predictions about the scope of context facilitation. Since Becker refers to the logogen model for an account of which words go into the context-induced verification set, the current formulation of the verification model also makes the same predictions.

All three models of context facilitation predict facilitation from single word contexts to be wide in scope. More specifically, these models predict that a single word context will facilitate recognition of any word that is highly related to it. Previous experimental studies have used stimuli derived from production norms. However, there are many word pairs that subjects will rate as highly related but which will not be paired in the word associate or category exemplar production tasks. Therefore, the wide scope of facilitation predicted by these models has not been sufficiently tested. In Experiment 1, the successive lexical decision task

is used to test whether the scope of facilitation from single word contexts is as wide as predicted by these models.

The spreading activation, logogen, and verification models, as currently formulated, do not provide accounts of facilitation from sentence frame contexts. With these contexts, both sentence comprehension processes and world knowledge come into play. For example, consider the two following sentence frames containing the same words in different orders: The cup was placed on the _____ and Placed on the cup was the _____. Sentence comprehension processes must be used to differentiate the meanings of these two sentence frames; world knowledge must be used to determine suitable completions, i.e., what cups are usually placed on (tables, saucers) and what can be placed on cups (saucers, but not tables). Clearly, this type of context has more of the properties of contexts encountered in typical reading tasks than do single word contexts, and therefore is important in the study of language processing. Previous studies of the effect of sentence frame contexts on visual duration thresholds (Tulving & Gold, 1963; Morton, 1964) and on lexical decisions (Schuberth & Eimas, 1977) have demonstrated facilitation only for words which subjects generate to complete the sentence. There are many words which subjects would not generate in a sentence completion task, but which do form acceptable completions or are related to the context in some way. It is unknown whether or not facilitation occurs for these words.

Three hypotheses about facilitation from sentence frame contexts will be tested in Experiment 2: a specific facilitation hypothesis, an

acceptable completion hypothesis, and a general facilitation hypothesis.[2] These hypotheses are derived from three models of facilitation from sentence frame contexts, as described below. All three models assume that both sentence comprehension processes and world knowledge are involved in determining the scope of context facilitation. It is of course logically possible that context facilitation is entirely due to the relationship of the target to the individual words in the context. However, a nonstructural hypothesis of this type, in which the syntactic and semantic structure of the sentence frame is irrelevant to context facilitation, does not seem plausible. Furthermore, it would not predict facilitation for some of the sentence frame-target word pairs for which Morton (1964) found facilitation in the threshold task.

According to the specific facilitation hypothesis, a sentence frame context will facilitate recognition only for those words that subjects generate when given the context as a prompt in a sentence completion task. That is, facilitation will occur only for the type of stimuli used in previous experiments. This hypothesis can be derived from a model which incorporates the notion of schemata as representations of world knowledge (Rumelhart & Ortony, 1977; Rumelhart, 1977, in press). Schemata are mental structures representing general concepts of objects, events, or situations. Each schema specifies the major elements of what it represents, and the interrelations of these elements. The elements can be viewed as slots or variables. The process of comprehension involves retrieving appropriate schemata and filling the slots with specific instances. To take a simple

example, a dinner schema might contain slots for appetizer, main dish, dessert, etc., as well as slots for time and setting. Understanding a description of a dinner requires filling these slots with the appropriate particulars found in the description. One of the important characteristics of the slots is that each one has associated constraints which specify the types of elements that can fill it. For example, the constraints would specify that steak is a likely main dish but lettuce is not. In addition, slots can have default values which are accessed when the input does not specify how the slot should be filled. For example, the default utensil for eating many foods might be a fork, rather than a spoon or a pair of chopsticks.[3]

Applied to context facilitation, the model claims that the sentence frame context enables the retrieval of a relevant schema. The context would usually contain sufficient information to fill some but not all of the slots. The default value for one or more of the unfilled slots would then be accessed. In the lexical decision and tachistoscopic recognition tasks, the default value is in some way primed, and this facilitates recognition. Since it is this default value that would be produced in a sentence completion task, this model predicts that facilitation will occur for the same words subjects produce as sentence completions.

According to the acceptable completion hypothesis, a sentence frame context will facilitate recognition for any word that forms an appropriate completion for that context. Therefore, this hypothesis predicts facilitation for all the words for which facilitation is predicted by the

specific facilitation hypothesis, plus additional words that would not be generated in the production task but which form acceptable completions. A schema model could also yield this prediction, but rather than just the default being primed, facilitation is predicted to occur for all words representing concepts that meet the constraints on the unbound slot(s). One way in which this might occur is compatible with the verification model. The verification set could be limited to those words that meet the constraints (i.e., that form reasonable completions of the context).

The third hypothesis, the general facilitation hypothesis, stems from the spreading activation and logogen models of facilitation from single word contexts, combined with some mechanism which determines completions for the sentence frames. According to this view, the context will prime (activate, increment the logogen counter for) the word or words that best complete the context. Therefore, facilitation is predicted for all the words which the specific facilitation hypothesis predicts will be facilitated. In addition, following the basic logic of the spreading activation and logogen models, facilitation is also predicted for any words that are highly related to these best completions. In the terminology of the spreading activation model, the context will activate some set of nodes, and this activation will spread to nodes closely linked to those in the initially activated set, thereby facilitating recognition. In terms of the logogen model, the context will provide some semantic features. A word that subjects generate when given the context would share a maximum number of features with the context. Words related to this generated word (which therefore share a

large number of features with it) will, on the average, share more semantic features with the context than words that are not related to the generated word. Therefore, the maximal amount of facilitation should occur for words that best complete the context, but some facilitation should also occur for words related to these best completions.

Experiment 1: Single Word Contexts

Experiment 1 was designed to provide information about the scope of facilitation from single word contexts. More specifically, it was intended to determine whether a context word will facilitate a lexical decision for all related words, or only those that subjects generate in response to the context in a production task. This experiment was run without knowledge of Fischler's (1977) study. The two are identical in basic logic and the results corroborate. However, the present study differs from Fischler's in several aspects of the procedures and in the stimuli.

Method

A successive lexical decision task was used. On each trial, the subject was presented with a string of letters (the context), made a word or nonword response, and then was presented with a second string (the target) and made a second response. There were four key sets of stimulus word pairs, two experimental and two control sets. One experimental set consisted of words that were often paired in an association production task (e.g. king queen, hammer nail, forest tree). This associated set provides a replication of the context facilitation effect with stimuli similar to

those used in previous studies. The second experimental set, the related set, consisted of pairs of words that subjects rated as highly related, but which were very rarely paired on an associate production task (e.g., snow rain, spin web, night dream). Note that all associated pairs are rated as highly related, but many pairs rated as highly related are never paired in the associate production task. That is, the set of associated pairs is a subset of the set of related pairs. The two other sets were the associated control set and the related control set. The target words in these sets were identical to the target words in the corresponding experimental sets, but they were paired with unrelated and unassociated context words. Facilitation is said to occur when the lexical decision for the target word is faster in the experimental condition than the control condition. The spreading activation, logogen, and verification models all predict facilitation for both sets, but previous studies have generally not tested whether facilitation will occur for the type of stimuli in the related set.

The four sets of word pairs were presented in two different conditions, normal presentation and visually degraded presentation. Meyer et al. (1974) and Becker and Killion (1977) have shown that stimulus degradation increases the size of the context facilitation effect for stimuli comparable to the associated set. The degradation condition was included because pilot work suggested that there might be only a small facilitation effect for the related set. It was reasoned that if facilitation does occur for this set of words, the inclusion of the degradation condition would maximize the probability of finding evidence of it.

Stimuli. A large set of potential stimuli was used in a norming procedure which included an association production task and a relatedness rating scale. The subjects for this norming procedure, as well as for the experiment itself, were University of Illinois students. No subjects took part in more than one task. In the associate production task, 49 subjects were given the context words as prompts and asked to produce three associates for each. In the relatedness rating task, 34 subjects were given the word pairs and asked to rate them on a 1 to 5 scale, ranging from not at all related to very related. The final stimulus sets were selected such that the associated and related sets had similar distributions of relatedness ratings, but differed on the association norms.

In the experiment, twenty word pairs were used for the associated set and forty word pairs for the related set. All of these experimental word pairs were fairly highly related and the mean relatedness ratings for the two sets were comparable: 4.2 (SD = .34, range = 3.4 to 4.7) for the associated set and 3.9 (SD = .26, range = 3.5 to 4.5) for the related set. As the experimental logic requires, the two sets differed on the frequency of association in the production task. The average percentages of subjects who produced the target word as their first associate to the context word were 57% (SD = 14.1, range = 35% to 84%) for the associate set and 3% (SD = 2.4, range = 0% to 8%) for the related set. The average percentages of subjects who produced the target word as one of their first three associates were 74% (SD = 14.1, range = 49% to 96%) for the associated set and 8% (SD = 5.5, range = 0% to 18%) for the related set. The two context

word sets were also equated as closely as possible for word length and word frequency. For the associated and related sets, respectively, the averages of the number of letters were 4.70 (SD = 1.8) and 4.65 (SD = 1.1), the averages of the number of syllables were 1.15 (SD = .366) and 1.20 (SD = .405), and the antilogs of the mean of the log word frequencies (Kucera & Francis, 1967) were 62.8 and 65.5. The control sets were formed by pairing the target words with context words from the original set used in the norming procedure but not used in the experimental sets. Two independent judges checked the control sets and agreed that none of the pairs were related. These stimuli are listed in Appendix A.

In addition to these critical stimulus sets, there were three other stimulus sets, each containing 50 stimulus pairs: word-nonword pairs, nonword-word pairs, and nonword-nonword pairs. The words in these sets were taken from those used in the norming procedure but not used in the word-word pairs. All nonwords followed the orthographic constraints of English and were therefore pronounceable. These stimuli were necessary for the experimental task, but do not provide any information about the scope of context facilitation.

Procedure. There were 40 subjects, 20 in the normal presentation condition and 20 in the degraded presentation condition. The four critical stimulus sets were each divided into two subsets. Each subject received only one of these subsets, arranged so that no target words were repeated for any subject. Ten subjects in each of the presentation conditions received each subset. Each subject received all of the stimulus pairs

containing nonwords. Therefore over the course of the experiment, each subject received 210 stimulus pairs: 10 associated, 10 associated control, 20 related, 20 related control, 50 word-nonword, 50 nonword-word, and 50 nonword-nonword pairs. Each subject received the stimuli in a different random order. The experimental trials were preceded by 30 practice trials, including some of each stimulus type.

The study was computer controlled, with each subject in a separate booth containing a typewriter keyboard and a CRT display on which the stimuli were displayed in uppercase letters. Each trial began with a fixation point centered on the screen. The trial was initiated when the subject pressed the space bar on the keyboard. After a delay of 350 milliseconds, the first letter string appeared, centered on the screen, where it remained until the subject responded by pressing either a yes or no key. There was a 350 millisecond delay between the response to the first string and the appearance of the second, which was also centered on the screen. The subject responded to the second string using the same yes and no keys. After the second response, if the subject was correct on both responses, the fixation point appeared and the subject could proceed to the next trial. When there was an error, the subject received a message saying whether the error was on the first or second word. This remained on the screen for three seconds, after which the fixation point appeared. Instructions to the subjects asked them to respond as quickly as they could while maintaining accuracy.

The procedures were identical for both presentation conditions, with one exception. For the degraded presentation condition, a transparency sheet made from a commercial dot pattern overlay (Zip-A-Tone 325-30) of 30% area coverage was placed over the entire CRT screen. Both the context and target words were visually degraded.

Results

The data to be reported are from the decisions on the target words in the four word-word stimulus sets. Table 1 shows the mean reaction times and error proportions for the eight cells formed by crossing the three independent variables of normal/degraded presentation, associated/related and experiment/control pairs.[4] The errors rates were less than 5% in all cells and do not show any significant differences. Therefore only the reaction time data will be discussed. Overall, the results show that there was a facilitation effect for both the associated and related sets and that subjects took longer to respond to degraded stimuli than to nondegraded stimuli. No other effects approached statistical significance. The related and associated pairs did not differ, and there was no evidence of interactions among the three variables.

Insert Table 1 about here

The degradation effect was significant in an analysis combining associated and related data (589 vs. 674 msecs), $\underline{\text{min}}F'(1,42) = 7.12$, $\underline{p} < .01$. It was also significant in separate analyses of the associated

data, $\underline{minF'}(1,49) = 6.68$, $\underline{p} < .05$, and of the related data, $\underline{minF'}(1,43) = 5.14$, $\underline{p} < .05$. The magnitude of the degradation effect ranged from 80 to 90 msecs in the four comparisons, and both $\underline{F}_1 < 1$ and $\underline{F}_2 < 1$ for all interactions involving degradation. That is, the expected increase in the context facilitation effect with degradation did not occur. Since the degradation factor did not interact with the others, the data from the degraded and nondegraded presentation conditions were combined for the analyses of the other factors.

As mentioned above, a significant facilitation effect was found. First considering the associated and related data combined, the experimental pairs were responded to more quickly that the control pairs (621 vs. 642 msecs), $\underline{minF'}(1,90) = 6.63$, $\underline{p} < .05$. The magnitude of this facilitation effect was not significantly different for the associated and related sets, as shown by the lack of any interaction, $\underline{F}_1 < 1$ and $\underline{F}_2 < 1$. Analyses of the associated and related sets separately showed parallel effects. The experimental and control word pairs showed significant differences in $\underline{F}_1$ and $\underline{F}_2$ ($\underline{p} < .05$), while in both cases $\underline{minF'}$ just failed to reach significance at the .05 level, $\underline{F}_1(1,38) = 6.15$, $\underline{F}_2(1,19) = 5.79$, $\underline{minF'}(1,50) = 2.98$ for the associated set, $\underline{F}_1(1,38) = 6.42$, $\underline{F}_2(1,39) = 8.11$, and $\underline{minF'}(1,76) = 3.58$ for the related set.

These results corroborate those of Fischler (1977) in providing evidence for the wide scope of facilitation predicted by the models. Two additional questions arise about these results: Why are the effects so much smaller than the 80-90 millisecond facilitation effects found by Fischler?

Why didn't degradation increase the size of the effect? The difference in the magnitude of the effects is apparently due to differences between the successive presentation procedure used here and the simultaneous presentation of the context and target words used by Fischler. In previous work by Meyer and his associates, larger effects have been found with simultaneous presentation. Meyer and Schvaneveldt (1971, Experiment 1) found an 85 millisecond effect with simultaneous presentation, while Meyer et al. (1974) found a 38 millisecond effect with successive presentation.

The lack of an interaction with degradation is more of a puzzle. It may be due to degrading both the context and target words and to using dot pattern degradation. Meyer et al. (1974) used dot pattern degradation, but degraded only the target word. Becker and Killion (1977) report an interaction of facilitation effects and degradation when both context and target words are degraded, but they used intensity degradation, and offer arguments that this may cause different effects than dot pattern degradation. Verification of this possibility would require further experimentation. Since it is not central to the aims of this paper, it will not be considered further.

Experiment 2: Sentence Frame Contexts

Experiment 2 tests whether facilitation from sentence frame contexts is limited to those words subjects generate to complete the sentence (the specific facilitation hypothesis), whether facilitation will also occur for other words which form acceptable completions of the sentence (the sentence acceptability hypothesis), and whether facilitation will occur for words

that do not form acceptable completions but which are related to the words subjects generate as sentence completions (the general facilitation hypothesis).

In this experiment, subjects determined whether strings of visually presented letters formed words, and reaction times and error rates were measured. Over the course of the experiment, each target word was presented both with and without a preceding context. However, comparisons of reaction times from sentence frame context conditions and no-context conditions are problematic. It cannot be assumed that faster reaction times in the context condition demonstrate context facilitation, nor that slower reaction times in the context condition demonstrate context interference.

Schubert and Eimas (1977) showed some concern for the problems involved. They examined the effects of sentence frame contexts on three types of target strings: congruous words, incongruous words, and nonwords. They used two control conditions, a no-context condition and a spelled digit string context condition (e.g., three six five nine). The intent of the digit context was to control for processing load. When compared to the digit string control condition, the results in the sentence frame context condition showed facilitation for all three types of targets, with the effect being largest for the nonwords, next largest for the congruent words, and smallest for the incongruent words. When compared to the no-context control condition, the results showed facilitation for nonwords and congruous words, but interference for incongruous words. Therefore, depending on which condition is taken as the proper control, sentence

contexts either facilitate or interfere with recognition of the incongruous words, and the magnitude of the facilitation effect for the other targets changes. The digit context, as compared to the no-context condition, increased reaction times about 70 msec for all target types.

Schuberth and Eimas chose to consider their no-context conditions as the most appropriate control. However, Kleiman (1977) found that minor changes in procedure in sentence frame context conditions can influence reaction times. In his first experiment, Kleiman found that for words that were the most common completions of the sentence frame contexts lexical decisions were slower in the context condition than in a no-context condition, but this finding reversed in his second experiment. The differences between the experiments were that in the second experiment there was an increase in the lag between the context and target string on each trial and a fixation point appeared before the target. These changes decreased reaction times in the context condition for all target types used in the experiments. The procedural changes could thereby influence whether reaction times in a sentence frame context condition are faster or slower than reaction times in a no-context (or any other) control condition.

In the study to be reported, the no-context condition serves to test whether the reaction times and error rates for the sets of target words are equivalent without any context effects. The data from the target word sets in the context condition are then compared with each other (not with the data from the no-context condition). Since the hypotheses to be tested are primarily concerned with which sets of words show context effects, it is not

critical whether a given difference is due to facilitation of one set or interference of another, or a combination of facilitation and interference (although this distinction is critical for other aspects of models of context effects). For example, the data will not enable us to distinguish between facilitation of words that form acceptable sentence completions and interference of words that form unacceptable completions. However, in either case, some process must distinguish acceptable from unacceptable completions and operate differently upon the two sets.

Despite this indeterminacy, it seems reasonable to assume that sentence contexts are more likely to facilitate word recognition than they are to interfere with it, since skilled readers process words in context so quickly. For this reason, and to simplify exposition, differences between target word sets in the context condition will be discussed in terms of facilitation.

Method

Stimuli. There were three sets of stimuli used to test the predictions which distinguish the hypotheses, with stimulus set being defined by the relationship of the target word to the sentence frame context. An example context is He hit the nail with the _____. Other sample stimuli are shown in Table 2. One set of stimuli contained words that formed best completions (BC), such as the word hammer for the above context. (All of the sentence frames used had a single generally agreed upon best completion.) All three hypotheses predict facilitation for this set. A second set of stimuli contained words highly related to the best completions, as determined by a

relatedness rating scale. Wrench would be a related (R) word for the above context. Some of these R words formed acceptable completions, while others did not (see Table 2). The general facilitation hypothesis predicts facilitation for the R set, whether or not the target word forms a reasonable completion of the sentence frame. The acceptable completion hypothesis predicts facilitation for those members of this set which form acceptable completions. The specific facilitation hypothesis predicts no facilitation for this set. The third set of stimuli contained words unrelated to the best completion. The word book would be an unrelated (U) word for the sample context. As for the R set, the words in the U set varied in how well they completed the context (see Table 2). Both the specific facilitation and the general facilitation hypotheses predict no facilitation for the U set. The acceptable completion hypothesis, of course, predicts facilitation for those members of this set that form acceptable completions.

Insert Table 2 about here

An additional set of stimuli contained nonwords as the target string (see Table 2). The nonwords all followed the orthographic patterns of English, and were therefore pronounceable. This set was necessary for the experimental task, but was not involved in any of the predictions that differentiate the three hypotheses.

A large set of potential stimuli was developed by the author. These were subjected to several norming procedures (described below) in order to determine stimuli sets with all the necessary characteristics. In this manner, a set of stimuli was developed, consisting of 42 sentence frames which each had one BC, one R, and one U word. These stimuli are listed in Appendix B.

The subjects for the norming procedures and the experiment itself were all Stanford University students, none of whom participated in more than one task. The potential BC words were checked by having 26 subjects complete the potential sentence frames with single words. For the 42 sentence frames, 78% of the completions were the appropriate BC words and only 0.7% of the completions were the R or U words. The relatedness of the BC and R words, and the lack of relatedness of the BC and U words, were checked by having 22 subjects rate the relatedness of the word pairs on a 1 to 5 scale, where 1 signified not at all related, 3 signified somewhat related, and 5 very related. The mean relatedness ratings were 4.1 (SD < .54) for the BC-R pairs and 1.9 (SD < .54) for the BC-U pairs.

As previously discussed, the words in the R and U sets varied in how well they completed the sentence frames. Twenty-two subjects rated how well each word completed its sentence frame, using a 1 to 5 scale where 1 signified the word doesn't fit the sentence at all and 5 signified the word fits very well. These ratings showed that the R and U sets of words contained equally good sentence completions. The mean ratings were 2.5 (SD = 1.0) for the R set and 2.6 (SD = 1.1) for the U set. These two sets

were also approximately equated for frequency. The antilog of the means of the logs of the Kucera and Francis (1967) frequency counts was 42 for the R words and 55 for the U words.

These stimuli were used in a preliminary study (reported in full in Kleiman, 1977). The results of this study showed a large facilitation effect for the BC set, but no other significant effects. In order to increase statistical power for the other comparisons of interest, in the present experiment a new set of 42 sentence frames, each with one best completion, replaced the BC set given in Appendix B. These replacement stimuli are listed in Appendix C. The sentence frames and target words for the R and U set were the same as those used in the preliminary study. Therefore, in the experiment to be reported, the stimuli consisted of 42 sentence frames, each with one R and one U word (listed in Appendix B), 42 different sentence frames each with one BC word (listed in Appendix C), and, in addition, 48 more sentence frames which were paired with nonword completions. These additional sentence frames were like the others in all apparent aspects, so subjects were unable to use characteristics of the sentence frame context to predict whether a word or nonword would appear.

Procedure and Design. The stimuli were presented in a tachistoscope with an effective viewing distance of 51 cm. All stimuli were typed on white cards using IBM orator type. In the trials without context, the subject saw a fixation point, pressed an onset button, and 600 msec later the fixation point disappeared and a string of letters appeared. Subjects decided whether or not the string of letters formed a word. They signalled

their response by pressing the appropriate response button, which they were instructed to do as rapidly as they could while maintaining accuracy. For the context trials, subjects pressed an onset button and the sentence frame appeared in the top half of the viewing field. They read the context once at their own rate and then pressed the onset button again. The sentence frame disappeared and a fixation point appeared in the bottom half of the viewing field. After a 600 msec delay, the fixation point disappeared and the string of letters appeared. Subjects then made their decision as in the no-context trials. To insure that they were reading the context, after the response on randomly selected trials, subjects were asked to report the context.

Each of the 12 subjects participated in two sessions, about one week apart. This allowed a full set of data (one observation for each word in both the context and no-context conditions) to be collected from each subject without repeating any words or contexts in the same session. In each session, the subject received one block of trials in the context condition and one in the no-context condition. Half of the stimuli from each set appeared in each condition. Each block of trials was divided into three sub-blocks, each containing 21 word trials (7 of each stimulus set) and 16 nonword trials. The order of context and no-context blocks, and the order of the sub-blocks, was counterbalanced across subjects, as were the sessions in which each word appeared with and without context. The stimuli within each sub-block appeared in a different random order for each subject.

Results

The main findings were: (1) A large facilitation effect for the BC set. This best completion effect was predicted by all three hypotheses. (2) Within the R and U sets, a facilitation effect for those words that formed reasonable completions for the sentence frames. This sentence acceptability effect was predicted by the acceptable completion hypothesis, but not by the others. (3) A facilitation effect for the R set (relative to the U set), independent of how well the word completed the sentence frame. This relatedness effect was predicted by the general facilitation hypothesis, but not by the others.

A preliminary analysis showed that reaction times were faster in the second session than the first, $minF'$ (1,25) = 13.56, $p < .01$. However, this effect did not interact with any others, so the data from both sessions were combined for the following analyses. The mean reaction times and proportion of errors for each stimulus set in the context and no-context conditions are shown in Table 3. The error data did not show any significant differences, so only the reaction time data will be discussed.

Insert Table 3 about here

Context differentially affected the three word types: The context by stimulus set interaction was significant, $minF'$ (2,86) = 54.69, $p < .01$. The differences among the stimulus sets in the no-context condition were not significant, $minF'$(2,119) = 1.43. The differences in the context condition

were significant, $\underline{\text{minF}}'(2,88) = 58.88$, $\underline{p} < .01$. As expected in this condition, mean reaction time for the BC set was significantly less than the other two sets, $\underline{\text{minF}}'(1,88) = 113.34$, $\underline{p} < .01$. In addition, mean reaction time for the R set was less than for the U set, $\underline{\text{minF}}'(1,84) = 4.42$, $\underline{p} < .05$.[5] Therefore, facilitation occurred for the words related to the expected words.

In order to test the acceptable completion hypothesis, an analysis taking into account how well each word completes the sentence frame is necessary. For the following analysis, the R and U sets were each divided into three subsets according to the rating of how well each word completed its sentence frame. The mean reaction times and error rates with context are shown in Table 4, divided into low, medium, and high sentence completion ratings (14 in each cell). The stimuli in the sentence completion categories are marked L, M, and H, respectively, in Appendix B. In the no-context condition, there were no differences among the reaction times for the corresponding word sets, $\underline{F}_1 < 1$ and $\underline{F}_2 < 1$. However, in the context condition data shown in Table 4, there was a significant sentence completion effect, $\underline{\text{minF}}'(2,60) = 3.49$, $\underline{p} < .05$.

Insert Table 4 about here

The sentence completion effect did not interact with the relatedness effect: The stimulus type by sentence completion interaction was not significant, both $\underline{F}_1 < 1$ and $\underline{F}_2 < 1$. Inspection of Table 4 shows that the

R - U difference is of the same magnitude in all three sentence completion categories. That is, there is facilitation of the R set even when the words did not complete the sentence in a reasonable way.

General Discussion

Experiment 1 provided evidence that a single word context will facilitate a lexical decision about words related to it, whether or not the context and target words are also associated. Experiment 2, which dealt with sentence frame contexts, yielded three main findings: (1) Decisions for best completions (BC set) were much faster than for words from other sets. (2) Among words not generated as completions, decisions were faster for words related to the best completions (R set) than for words unrelated to the best completions (U set). (3) Also among words not generated as possible completions, decisions were faster for words that formed acceptable completions of the sentence frame than for words that did not. These relatedness and sentence acceptability effects were found to be additive: The sentence completion effect occurred in both the R and U sets, and the R-U difference was the same when the target word was an acceptable completion of the sentence as when it was not. These results provide evidence of a wide scope of facilitation.

The logogen, spreading activation, and verification models all offer accounts of the effects of single word contexts. However, they do not take into account the sentence comprehension processes and world knowledge necessary to determine best completions and acceptable completions. Therefore, these models cannot offer adequate accounts of the effects of

sentence frame contexts. On the other hand, a schema based model, such as that from which the sentence acceptability hypothesis was derived, can account for the best completion and sentence acceptability effects, but does not provide any account of the relatedness effect, or of the single word context results.

In order to account for the entire set of results, a model must combine aspects of models of single word context effects with processes of sentence comprehension and the use of world knowledge. A speculative combination model, which uses the construct of schemata in conjunction with a semantic network and the principles of spreading activation, is outlined below. A combination model of context facilitation might account for the results of Experiments 1 and 2 as follows. The account of the single word context effects would be identical to that offered by the spreading activation model already discussed. That is, single word contexts do not result in the use of schemata, since there is not sufficient information to enable the retrieval of appropriate schemata or the filling of any slots. A sentence frame context, however, does provide sufficient information to result in the retrieval of appropriate schemata and to fill some, but not all, of the slots. For one or more of the slots that are not bound, the default value and the constraints operate upon the semantic network to activate particular nodes. The default value activates the node representing it in the semantic network. For example, if the context is He threw a rock at the house and broke a _____, the default value most commonly accessed would be window. Since the node representing the default value is directly activated, the

word window will show a large facilitation effect. Activation will then spread from this node to related concepts, thereby producing facilitation for highly related words (e.g., door), whether or not they form acceptable completions.

The operation of the constraints upon the semantic network causes the sentence acceptability effect. These constraints are themselves concepts, and therefore will be represented by nodes in the semantic network. For example, the constraints resulting from the context given above would specify that an acceptable completion must be part of or found at a house, must be a physical object, and must be breakable. According to the model, the schema acts upon the semantic network to activate the nodes representing the constraints, and this activation then spreads from these nodes. Any word that forms an acceptable completion must represent a concept that meets the constraints. It is assumed that concepts meeting the constraints are closely linked to the nodes representing the constraints. Therefore, activation will spread from each constraint node to those nodes representing acceptable completions, thereby facilitating recognition. That is, acceptable completions for the above example (e.g., dish, door, etc.) will have the properties of being physical objects, breakable, and found at houses, and therefore nodes representing these acceptable completions will be linked to the nodes representing these constraints. Since the acceptable completion nodes are not directly activated, the amount of facilitation will be smaller than for the best completions, which are directly activated. In addition, since the relatedness and sentence acceptability effects are

determined by different initial activations, they would be predicted to be independent effects, as was found in Experiment 2.

A combination model of this sort is consistent with several previous proposals. Ortony (1978) has found a model combining schemata and semantic networks useful in accounting for different sets of data than those considered here. Anderson's (1976; Anderson, Kline, & Lewis, 1977) ACT model combines a network representation in which spreading activation occurs with a production system. The production system consists of rules which operate when specified conditions occur in the activated nodes of the network. Within the ACT model, schematic knowledge could be represented as production rules. Anderson suggests that the combination of these two types of processing enables an efficient system, since spreading activation determines a limited portion of the network against which the conditions of the production rules are matched. Collins and Quillian (1972) also present a model of language comprehension which, in addition to a semantic network and spreading activation, includes procedures that operate upon the activated nodes in the network. The value of combination models such as these is well stated by Winograd (1977):

> Semantic networks are the only representation I have described which concentrate on the problem of retrieval--how to find the set of facts relevant to a given problem. The others have concentrated more on how to apply the facts when they are found. The two ideas might well be combined, since the strength of network systems is more in finding connections than in making use of them. (p. 60)

The data reported here lend empirical support to the need for such a combination.

Reference Notes

1. Meyer, D. E., Schvaneveldt, R. W., & Ruddy, M. G. Activation of lexical memory. Paper presented at the meeting of the Psychonomic Society, St. Louis, 1972.

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Footnotes

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[1]The study by Fischler appeared after the experiments reported here were completed. As will be discussed, Fischler's study is similar to Experiment 1 reported here.

[2]These three hypotheses are discussed in terms of predicted facilitation effects. However, as will be discussed further under Experiment 2, with sentence frame contexts it is not clear how to discriminate facilitation for a given set of words from interference for the comparison set. Since the hypotheses to be tested are primarily concerned with the scope of context effects, whether a given effect is due to facilitation or interference is not critical here, although it is important for other aspects of models of context effects (cf. Neely, 1977).

[3]This description of schemata neglects complications not critical to this discussion, such as how the filling of some slots can influence the constraints on others and whether the default values are retrieved or inferred.

[4]All means presented in the text and tables are the means of the subject means. Reaction times from error trials and times more than three standard deviations from the subject's mean for a given condition were excluded from the data analysis.

[5]A difference between the R and U sets of comparable magnitude was found in the preliminary study, although it was not statistically significant (Kleiman, 1977, Experiment 1).

Table 1

Mean Reaction Times (and Error Proportions) for Experiment 1

	Associated	Associated Control	Related	Related Control
Normal Presentation	571 (.03)	595 (.02)	588 (.02)	601 (.03)
Degraded Presentation	656 (.02)	680 (.03)	668 (.04)	691 (.04)

Table 2

Sample Stimuli for Experiment 2

The cup was placed on the

table (best completion = BC)

chair (related to expected word = R) } acceptable completions

floor (unrelated to expected word = U) }

The king of the beasts is the

lion (BC)

roar (R) } anomalous completions

work (U) }

He needs a new pair of laces for his

starn (NONWORD)

Table 3

Mean Reaction Times (and Error Proportions)

in Context Condition for Experiment 2

BC	R	U
444 (0)	533 (.02)	555 (.04)

Table 4

Mean Reaction Times (and Error Proportions) for R and U Words, Divided into Low, Medium, and High Sentence Acceptability Ratings Sets

	Low	Medium	High
R	555 (.04)	524 (.03)	520 (.01)
U	582 (.08)	550 (.04)	542 (.02)

Appendix A

Stimuli from Experiment 1

Associated and Associated Control Sets

	Control Context	Associated Context	Target Word
1	hotel	ale	beer
2	teeth	author	book
3	jump	eat	food
4	salad	king	queen
5	mountain	speak	talk
6	garage	coal	black
7	cow	scissors	cut
8	soldier	goblet	glass
9	picture	pilot	airplane
10	kitchen	add	subtract
11	wood	wheat	bread
12	radio	week	day
13	song	hammer	nail
14	toaster	dream	sleep
15	poet	dry	wet
16	sign	dog	cat
17	sound	thin	fat
18	dish	thunder	lightning
19	dance	sandpaper	rough
20	snake	forest	tree

Related and Related Control Sets

	Control Context	Related Context	Target Word
1	dress	red	apple
2	camp	money	buy
3	school	rocket	fast
4	sneeze	woman	girl
5	stomach	whisper	low
6	child	grapefruit	orange
7	road	market	sell
8	fraction	burn	smoke
9	hill	taffy	sweet
10	wallet	spin	web
11	tractor	pillow	bed
12	bell	bench	chair
13	wax	water	fish
14	train	love	happy
15	basket	father	man
16	river	hot	pepper
17	chalk	booties	shoes
18	lamp	marble	smooth
19	paper	high	tall
20	spice	wedding	white

	Control Context	Related Context	Target Word
21	chain	egg	bird
22	ship	milk	cookie
23	tennis	plant	flower
24	beach	diamond	hard
25	floor	sky	moon
26	pond	cup	pint
27	game	small	short
28	taste	rise	stand
29	turn	yarn	thread
30	ritual	bride	wife
31	barn	sea	blue
32	poster	night	dream
33	bacon	boot	foot
34	ball	farm	house
35	carpet	clinic	nurse
36	fence	snow	rain
37	phrase	wash	shower
38	friend	coat	sweater
39	towel	jungle	tiger
40	tool	foam	soft

Appendix B

Sentence Frames, BC,* R, and U Words for Experiment 2

	Sentence Frame	BC Word	**R Word	**U Word
1.	All the clothes the mourners wore were	black	M white	M dirty
2.	Fluttering by was a pretty	butterfly	H insect	H leaf
3.	The barbells the strong man lifted were very	heavy	H light	H old
4.	The basketball players were all very	tall	H short	H nervous
5.	The man who didn't eat all day was very	hungry	M thirsty	M lazy
6.	The cup was placed on the	table	H chair	H floor
7.	The parking lot was filled with	cars	H trucks	H trash
8.	He threw a rock at the house and broke a	window	M door	M dish
9.	No one at the zoo knew the name of the strange	animal	H dog	H visitor
10.	The surprise party made him feel very	happy	H sad	H tired
11.	In autumn he went looking for pretty colored	leaves	H trees	H clothes
12.	It was a very dark	night	H day	H room
13.	On a hot summer day many people go to the	beach	M sand	H theater
14.	The magician took out his hat and made a rabbit	appear	L see	L laugh
15.	The mother fed the newborn	baby	L diapers	L radio

16.	The tired mother gave the dirty child a	bath	H	towel	H cookie
17.	On top of the hamburger there was melted	cheese	L	mouse	L plastic
18.	He bought a wall-to-wall	carpet	M	drape	H poster
19.	The trained seal performed a clever	trick	M	joke	M song
20.	They baked many loaves of	bread	L	cake	L clay
21.	He put a clean sheet on the	bed	M	pillow	M ground
22.	The king of beasts is the	lion	L	roar	L work
23.	The sick man had only six months to	live	M	breathe	M pay
24.	He always forgets because he has a poor	memory	L	think	L speech
25.	The hikers slowly climbed up the	mountain	H	valley	M stairs
26.	The sad ending made many people	cry	M	tears	H leave
27.	Eat right for good	health	M	medicine	L money
28.	The child was frightened, but it was just a bad	dream	H	night	M picture
29.	She sewed the button on with some thread and a	needle	L	sharp	L heavy
30.	The Atlantic is a vast	ocean	M	water	M plain
31.	He has trouble adding and subtracting large	numbers	L	letters	L weeks
32.	In the crowd there were all kinds of	people	L	places	L tools
33.	While skiing he broke his	leg	M	shoe	L hat
34.	The old horse moved very	slowly	H	fast	M often

35.	Almost everyone has ten	fingers	M gloves	H pencils
36.	There are two pints in a	quart	L milk	L recipe
37.	The orchestra played very pretty	music	L noise	L shells
38.	He sanded the wood until it was	smooth	L hard	M broken
39.	While the national anthem plays, everyone is expected to	stand	L sit	L turn
40.	He hit the nail with a	hammer	H wrench	M book
41.	Last night there was a full	moon	M sky	M party
42.	He was stung by a	bee	L flower	M fish

*The BC words listed here were used to determine the R and U words. The BC stimuli actually used are listed in Appendix C.

** H = high sentence acceptability set

M = medium sentence acceptability set

L = low sentence acceptubility set

Appendix C

BC Set Sentence Frames and Words

for Experiment 2

1.	He was so frightened he was white as a	ghost
2.	Three heavy bags is more than he can	carry
3.	More money buys fewer products during times of	inflation
4.	Three people were killed in a terrible highway	accident
5.	The defendant is charged with	murder
6.	The heavy rains caused a massive	flood
7.	The baby weighed six pounds at	birth
8.	I can't write on the blackboard without any	chalk
9.	For breakfast she wanted bacon and	eggs
10.	At noon they took a break for	lunch
11.	Lincoln was born in a log	cabin
12.	The children enjoyed the three ring	circus
13.	He campaigned so he would win the	election
14.	He can't hear you because he is	deaf
15.	December is the last month of the	year
16.	The prisoners were planning how they would	escape
17.	To keep animals out of the garden, he put up a	fence
18.	He forgot to buy something, so he went back to the	store
19.	The politician spoke out for law and	order
20.	A red light is a signal to	stop

21.	The new store had a grand	opening
22.	To help wake up, he needed a cup of	coffee
23.	After being robbed, he called the	police
24.	It's unlucky to walk under a	ladder
25.	The lecture should last about one	hour
26.	The careless smoker caused a forest	fire
27.	He had to wake up early to get there on	time
28.	He was lucky enough to win first	prize
29.	The prison sentence was only six	months
30.	There have been two world	wars
31.	Some say a dog is man's best	friend
32.	It felt much colder when the sun was behind a	cloud
33.	Because he had a toothache, he called the	dentist
34.	The old man has a long gray	beard
35.	After a long wait, the package finally	arrived
36.	The wet clothes were hung outside to	dry
37.	The underpaid workers went on	strike
38.	When he was 65, he had to	retire
39.	Hawaii is the newest	state
40.	He died of a heart	attack
41.	The over-weight man went on a	diet
42.	The minister pronounced them man and	wife

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